

Environmental management based on regulatory compliance in stone aggregate mining

Gestión ambiental desde el cumplimiento normativo en la minería de agregados pétreos

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Abstract

Goal: To conduct a study on environmental management from the perspective of regulatory compliance in stone aggregate mining in the Department of La Guajira, Colombia.

Methodology: The methodology applied was qualitative with a non-experimental approach. The study population comprised the following mines: Agregom Ltda, Agregados Rio Negro, and Orion Asfaltos y Concretos S.A.S., all of which were producers and marketers of construction materials. Regarding the information gathering process, an instrument was utilized featuring environmental management as a nominal variable, focusing on 2 dimensions and 10 indicators. In addition, structured field visits were conducted. The validity and reliability of the study were evaluated based on criteria established by experts in environmental regulations as management tools.

Results: The findings revealed that companies engaged in exploiting stone materials degrade environmental factors such as air, water, soil, atmosphere, fauna, and flora, largely due to non-compliance with Colombian environmental regulations mandated by the Regional Autonomous Corporation of La Guajira.

Conclusions: Organizations lack strategic plans focusing on environmental management measures, hindering the consolidation of environmentally sustainable mining in the department.

Keywords: Environment, Management, Regulations, Measures, Mining, Stone

Abstract

Objetivo: Estimar la energía disponible para generar electricidad a partir de biogás de vertedero utilizando el modelo LandGEM adaptado a las condiciones locales de Montería, Colombia.

Metodología: Para ello se obtiene de base de datos y estudios la información del relleno sanitario de residuos Loma Grande ubicado en la ciudad de Montería, volumen de residuos, clima y composición de residuos para el periodo 2016-2028, para aplicar el modelo LandGEM a la producción de energía de biogás.

Resultados: se observó que solo para el año 2022 la cantidad de metano calculada es de 9.984.000 m³/año y con esto la energía estimada total es de 268.4968 MWh, que podría suministrar los requerimientos del relleno sanitario Loma grande.

Conclusión: El estudio predice que estos modelos de evaluación se pueden utilizar para planificar la producción de energía a partir de gas de vertedero, y así, aprovechar la propiedad de terrenos improductivos que normalmente se utilizarían como vertedero y que se crearon previamente para materiales contaminantes no destructivos.

Palabras clave: Ambiente, Gestión, Normatividad, Medidas, Minería, Pétreos

Introduction

Nowadays, humanity is being called upon to confront significant environmental challenges related to climate change and high levels of natural resource degradation [1]. However, population growth and demographic expansions necessitate an accelerated demand for consumer goods, thereby increasing the utilization of raw materials across various industries to meet the needs of the global market [2].

Mining activities have been developed since ancient times, generating economic benefits in various regions. However, the operational actions implemented to obtain materials result in significant environmental damage, as evidenced by changes in land use, decomposition of soil properties, alteration of natural biological cycles, massive production of greenhouse gases, and even extinction of fauna and flora species [3]. The mining of stone materials has gained prominence in the market due to its benefits in asphalt mixtures. Their main characteristics include durability, resistance, and affordability. These factors have positioned them as highly valuable products in industrial terms.

Notably, the type of material produced from stone aggregates is directly related to granular bases, concrete in the fresh and hardened state, and it can be tailored according to clients' needs within its variation lines [4]. The processes necessary to obtain this type of materials range from exploration and extraction to exploitation phases in crushing plants, which source their raw materials from different alluvial sources. This productive chain results in environmental damage that threatens the conditions of the areas where they are developed if the plans and programs established by the environmental control agencies of the territory are not enforced. At the same time, they can affect the health of people exposed to long working hours. Some of the main symptoms found are related to mild and constant headaches, dizziness, mild or severe deafness, and migraines [5].

For its part, Latin America is consolidated as one of the richest territories in construction materials. The importance of these large deposits stems from their location and the variety of minerals they contain. This provides the population with the opportunity to engage in economic activities related to the production of derived materials [6]. Thus, mining is considered a valuable and significant activity that creates both formal and informal jobs in communities, leading to a substantial economic impact on Latin Americans.

In this regard, [7] argued that mining is key to understanding the great progress civilizations have made. However, its large-scale consolidation continues to be a matter of debate among major environmental organizations. One of the consequences of mining is its contribution to the GHG problem. During its activities, mining generates compounds such as carbon monoxide, sulfuric acid, and methane, with the latter being cataloged as one of the most harmful and significant contributors to climate change on planet Earth [8]. Therefore, territorial governments have established regulations governing the proper use of natural resources to protect ecosystems and human health [9].

While it is true that sustainable development focuses on safeguarding environmental resources for future generations to use for subsistence purposes, this concept is closely tied to fostering a strong environmental culture and rationality. Together, these elements form the key pillars of what today is known as "environmental management" [10]. In Latin America, the challenges related to environmental regulations are focused on protecting the environment and regulating the use of resources through organizations such as AIDA, the only regional organization of environmental legal experts [11].

Thus, environmental management is decisive, serving as an instrument aimed at consolidating sustainable development focused on the creation and integration of environmental policies for the effective use of natural resources. In the specific case of Colombia, environmental management processes are governed by regulations established by the Ministry of Environment. They play a vital role in strengthening the environmental responsibility of companies [12]. Notably, the applicable principles are outlined in ISO 14001 (2015), which mandates the preparation of environmental management plans to integrate the Sustainable Development Goals (SDGs) into the phases or procedures necessary to control the environmental impact of any project, work, or activity [13].

Environmental regulations are structured by international organizations across continents. In some countries, there are bodies of maximum authority who are in charge of the creation, issuance, and monitoring of compliance with these regulations in a gradual manner depending on their incidence [14]. It is necessary to emphasize that non-compliance with the regulations, laws, and/or decrees established by judicial bodies brings about consequences in the mining field, such as environmental sanctions, written warnings, and temporary closures, resulting in a direct economic loss. The extent of the sanction may increase if it is considered that the project represents a risk for any environmental factor, such as the impact on endemic species in danger of extinction and the alteration of a protected area, leading to the complete closure of the production unit [15].

Thus, in Colombia, any organization or industry, company, mine, or association must invest part of the economic resources they produce to set up environmental management measures planned in a schedule and flowchart of investments over time [16]. The main goal of this action is to ensure the integrity of resources moderating the level of damage caused by the activities developed and promote sustainable development and added value to organizations. However, illegal mining is expanding in the Colombian territory, leading to large hectares of degraded land, contamination of water basins, deforestation, and ecosystemic alterations. Since 2015, the country has been on alert due to the gradual increase of these consequences [17]. It is estimated that illegal activities have already reached 50% of Colombia's extractive production.

Similarly, [18] mentioned that the exploitation of alluvial materials involves exploration and extraction phases that generate changes in land use, loss of vegetation cover, and degradation of chemical components. Furthermore, [19] determined that the exploitation of this type of materials for construction causes toxic gases and particulate matter, thereby contributing to the atmospheric pollution caused by tailings, operation of crushing machines, stockpiling, and loading and unloading of stone material. This type of environmental impact causes alterations in the ecosystems in the production area and neighboring areas, depending on the production magnitude and type.

Along these lines, Colombia's regulations are framed in the Political Constitution of 1991, an essential pillar to promote the effective use and exploitation of natural resources. However, since the consolidation of the highest environmental body, specific regulations, laws, and decrees have been established for each production activity to create a horizon toward the SDGs [19]. Moreover, regional autonomous organizations work to ensure that actions are undertaken in each department to preserve the environment. These entities are in charge of granting the permits for use, exploitation, and environmental licenses, subject to a set of considerations determined by control, follow-up, and monitoring. [20] The regulatory provisions on the production of alluvial materials are issued through administrative records, ensuring that each organization complies with resource use, discharge management, comprehensive solid waste management, atmospheric emission permits, noise control, water use concession permits, and forest exploitation [21].

The Caribbean Region of the Colombian territory significantly contributes to the economy due to its high energy mining value. It actively participates in the National Development Plan by strengthening export alliances, particularly because it has the largest open-pit coal deposit in the world, known as Cerrejón, covering 6,900 hectares [22]. However, the environmental conditions of this area are affected by these activities. The most frequent problems include the pollution of water bodies and air, in addition to the deficit caused by the low quality of basic sanitation services, thereby reducing the quality of life for inhabitants [23].

The Department of La Guajira stands out for abundance of mineral wealth. Coal and salt are considered to be the main raw materials in this territory, which is also related to clay, gypsum, and stone aggregates. This helps in understanding the importance of this department for the progress of the Caribbean Region [24, 25]. Mining activity in the Guajira territory causes a negative environmental impact. The implementation of management plans can minimize and control the effects of environmental factors, thereby contributing to the preservation of ecosystems and the sustainable development of the organizations' production.

In this sense, mining continues to be classified as one of the most damaging activities for natural environments [26]. Therefore, it is crucial to identify specific actions closely tied to the regulations required by the Autonomous Corporations of each region. In the Department of La Guajira, there is a low percentage of specific studies on the environmental regulations of mines dedicated to the exploitation of stone materials [27]. Therefore, this study aims to examine compliance with environmental regulations in this type of mining organizations to determine their impact on environmental management processes.

One of the requirements to be met by producing companies is to have an emissions permit as per the conditions of Article 2.2.5.1.7.2. of Decree 1076 from 2015. This article regulates the use of the crushing machine, considered a fixed source of particle discharges harmful to the environment. [28] argued that many mining companies that exploit stone materials lack consultancy services for effective processes, thereby negatively impacting the environment and creating sectoral and social impacts.

Specifically, for the use of water resources, it is necessary to request a concession permit for water use when it is captured from a surface source. This is because if this resource is used by an organization without the proper permit, it is a crime subject to judicial reprimands. In addition, this type of company must be integrated into a program for efficient water use and saving, as required by Law 373 of 1999 [29]. For solid waste management, the Corporation requires the classification and separation of solid waste, as this is a severe problem in La Guajira and at the national level.

Regulations are essential for organizations, and compliance of environmental standards by mining companies is an essential pillar to preserve the environment. National requirements are still clear on what must be complied with; however, there exists a gap in the application and compliance with the requirements from the mining sector [30]. This gap affects the environmental responsibility of mining companies, adversely affecting the environment through soil degradation, air pollution, biological degradation, among other consequences affecting the ecosystem balance.

Finally, the inclusion criteria in the study of the companies Agregados Rio Negro, Agregom Ltda., and Orion Asfaltos y Concretos S.A.S., directly relate to the fact that their jurisdiction is in the Guajira territory, their corporate name, and their impact on the production of construction materials. At the same time, there is a need to study the regulatory management processes within the department, thereby contributing to the literature of this frame of reference.

Methodology

The study methodology adopted was qualitative, given that it did not involve aspects susceptible to quantification. This approach is widely used in scientific studies due to its flexibility and broad scope, offering the possibility of being a baseline for future research even in fields that are usually overlooked [31]. The research design is focused on the non-experimental field; therefore, situations are observed and analyzed as they occur naturally without randomly manipulating variables or situations [32].

The research was approached from the scope of stone aggregate mining, i.e., the study population comprised mines dedicated to this activity in the Department of La Guajira (see Table 1). Specifically, the mines under study included Agregom Ltda, Agregados Rio Negro, and Orion Asfaltos y Concretos S.A.S. All three use stone aggregates as raw materials to obtain construction materials as the final product. These organizations have in common the central structure of labor category for the development of the production phases and needs of unitary processes.

The similarity in the operation method of the organizations revolves around the fact that they all have a general manager in charge of creating the action plan to be executed. The rest of the personnel are in charge of several tasks, including control of crushing machines, handling of heavy machinery, loading and unloading raw materials or processed material, stockpiling material, among other essential processes for proper unit operation.

Table 1. Study population and general labor category

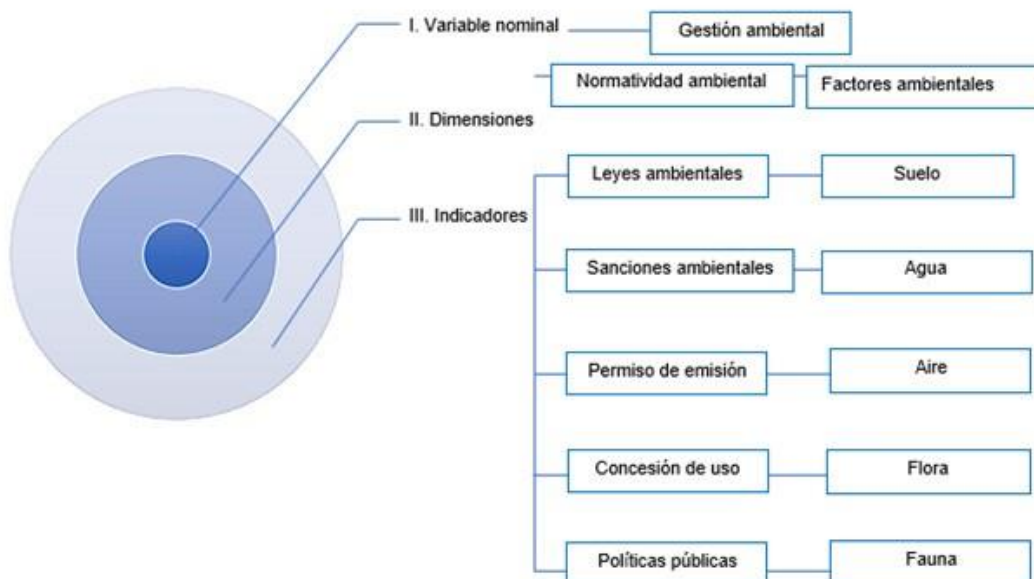
Company Name	Municipality	workers per	General labor category
AGREGOMLTDA	Albania	21	General Manager Production Engineer Environmental Engineer Supervisor Crushing Plant Operator Plant Assistants Loading Operator Dump truck driver Mechanical Assistant Watchmen
SY CONCRETOS S.A.S.	Riohacha	24	
AGREGADOS RIO NEGRO	Dibulla	25	

Source: Prepared by the authors

The main instrument of the study is a form composed of the nominal variable environmental management, complemented by 2 dimensions and 10 indicators ranked in order of importance according to the author's criteria. Within today's research world, forms are categorized as evaluation tools that strengthen qualitative studies by establishing the cause-effect relationship of an existing reality interdependent on random variables [33]. Moreover, developing these types of instruments allows for conducting a correct evaluation including aspects suited to the necessary context [34].

The study methodology includes data collection techniques categorized as primary sources of information [35], which ensures that this type of source provides the possibility of consolidating implicit information based on theoretical support from the study perspective. Collection instruments are represented in field observation, audiovisual material, review, and documentary analysis of scientific material (journals, books, and articles).

Figure 1. Hierarchy of the main instrument



Source: Prepared by the authors

Given that compliance with environmental regulations was evaluated from the perspective of environmental management, it was necessary to analyze the rules, laws, and decrees issued by the Ministry of Environment of the Republic of Colombia, the body in charge of issuing guidelines in terms of environmental integrity at the national level. Moreover, it was of great interest to identify the impact of the Regional Autonomous Corporation in its monitoring processes. The Corporation are in charge of granting permits for the use of natural resources at the departmental level [36] and ensuring the implementation of management measures to safeguard the integrity of ecosystems and surrounding areas, where production units are located.

Furthermore, field visits were conducted in each company along with the corresponding general manager. During the tour visits, production phases, type of machinery used, and material collection areas were identified. The effects of each factor were evidenced from an environmental perspective. Once this information was collected, the analysis phase began within the framework of the descriptive research. The impact of production activities on the surrounding areas was also considered.

The instrument used was a key tool in determining that the rules were being applied in organizations exploiting and using stone aggregates in environmental management, as verifying that their actions were in line with national regulations was crucial. For the final creation of the instrument, experts in environmental legislation, monitoring, and care of environmental factors were consulted.

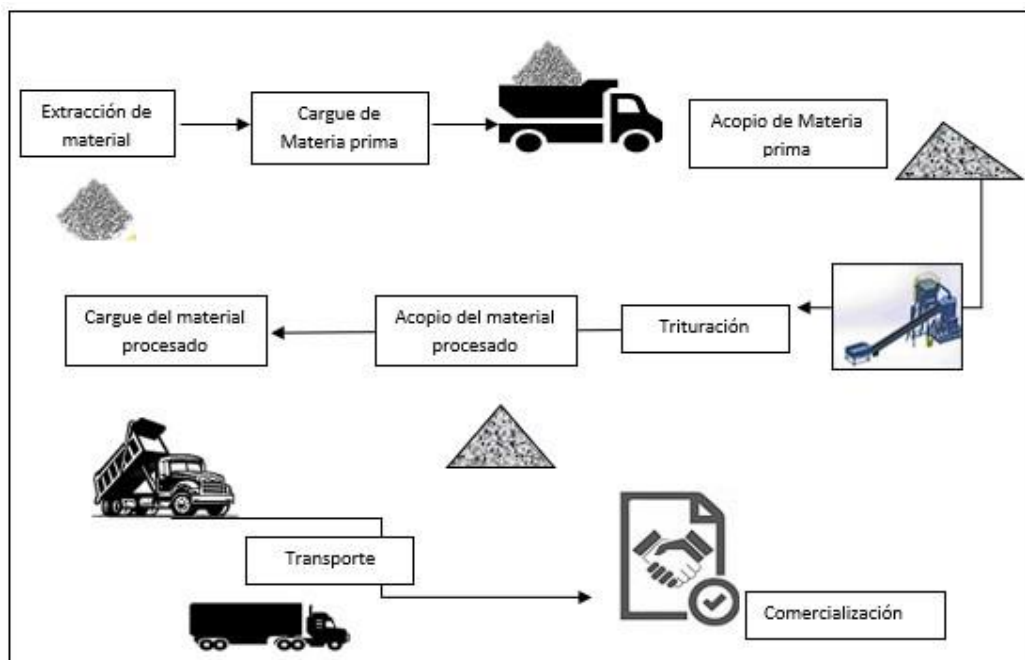
Finally, for the implementation of this research, no statistical procedures or formulas associated with any type of process were implemented, adopting a non-experimental approach. The validity and reliability of the instrument were supported by the judgment of experts [37], an accurate method to verify that a study is reliable when dealing with qualitative research. Through this, it is intended to provide a foundation for environmental management studies in the Department of La Guajira.

Results

The companies under study were Agregom Ltda., Orion Asfaltos y Concretos S.A.S, and Agregados Rio Negro. To develop the production stages of stone aggregates used as construction materials, these companies chose to implement a diagram in which they included essential processes to keep a production line contributing to economic sustainability (see Figure 1). The social impact of these types of mining activities in the Department of La Guajira was observed to be significant. These companies provide livelihoods for 70 people in the region, thereby improving their life quality.

In this regard, [38] mining entails development. It also affects ecosystems and human health due to the degradation of environmental factors, which may be reflected in the short, medium, or long term, depending on the intensity of exploitation and the type of machinery used. Furthermore, the raw materials used to create construction materials are stone aggregates of different dimensions, which possess properties that make them resistant and versatile to use. As for the machinery used for extraction, processing, and commercialization, the three companies manage the same diagram and are equipped with their own machinery to extract the material. For extraction, they use backhoes, picks, and shovels; for processing, they have a crusher that may be the central axis of the production unit, and without it, operations are paralyzed; for loading, unloading, and commercialization processes, they use loaders and tractor-trucks.

Figure 2. Stone aggregate production diagram



Source: Prepared by the authors

Regarding field visits, the first environmental impact is associated with landscape transformation. Orión Asfaltos y Concretos S.A.S. has a total area of 50,000 m², of which 20,000 m² are adapted for primary production phases. Agregados Rio Negro has an area of 93,000 m², of which approximately 40% are specifically allocated to develop production works in this mine. The areas where the greatest landscape transformation can be observed are in maintenance workshops, processing plant, storage center, and near the riverbed, where there is geomorphological alteration caused by traffic and the extraction of stone aggregates. Of the three companies, Agregom Ltda. has the largest area (750,000 m²), of which 38% are being used. This company has the greatest environmental damage due to extraction, resulting in soil degradation, loss of topsoil, alteration of soil patterns, and fauna migration.

Figure 3. Evidence of landscape transformation caused by mining of stone aggregates



Source: Authors' photographs

Along the same lines, Colombian regulations seek to regulate the damage caused by production activities to the natural environment. Therefore, environmental laws are considered within the exploitation of stone aggregates as a set of regulations to be followed to contribute to environmental conditions. The implementation of environmental laws encourages the rational use of natural resources [39] and safeguards raw materials for many industries in the long term, especially for companies that currently do not have a strategic plan designed to mitigate, control, or restore the environmental damage caused by their production activities.

In Colombia, any work requiring the use of natural resources should have an operating permit or preferably an environmental license. This is provided for in Law 768 of 2002 and is supported by Decree No. 2820 from 2010, currently in force. It was observed that Agregom's mine, in terms of environmental management, is covered by mining title No. HJ6-08111 of the MAJO exploitation front of mining company La Milagrosa. It operates with an environmental license granted through Resolution 1926 of 2008 issued by the Ministry of Environment and Sustainable Development, which is of national scope, as modified by Resolutions 0372 of March 14, 2013; 0944 of June 19, 2013; and 1316 of August 5, 2014. Agregom has had no problems in terms of atmospheric emissions.

Since the beginning of its activities as an organization in 1994, the Agregados Rio Negro's mine holds an environmental license. In 2017, as per record No. 1206 of November 21, during the visit of the Regional Autonomous Corporation, it received a warning regarding the operation of the main crusher plant. Thus, Agregados Rio Negro's mine operates without an

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atmospheric emissions permit for fixed sources specifying the operation of the crushing plant. Through the official letter ENT-1580 of March 2017, the Corporation, after performing the review, required Agregados Rio Negro to fill out a single form with all the specifications required by Decrees 02 of 1982 and 948 of 1995 issued by the Ministry of Environment and Sustainable Development, of national scope. In 2023, the company states that the regulatory permit is under process.

As for the mine of Orion Asfaltos y Concretos S.A.S., its application processes for emissions were delayed. Therefore, in 2019, it was environmentally sanctioned with the temporary closure of the mine. However, in 2020, it resumed its production operations. Currently, the company has an emission permit granted by means of Resolution No. 0950 of 2021.

Therefore, it is important to create a parallel scenario (see Table 2) between the environmental standards required for the implementation of aggregates production activities and the relation between compliance and non-compliance of the companies Orion Asfaltos y Concretos S.A.S., Agregom Ltda., and Agregados Rio Negro. In the table, compliance with the standard is (yes), non-compliance with the standard is (no), and if the company is not associated with these types of processes it says (does not apply).

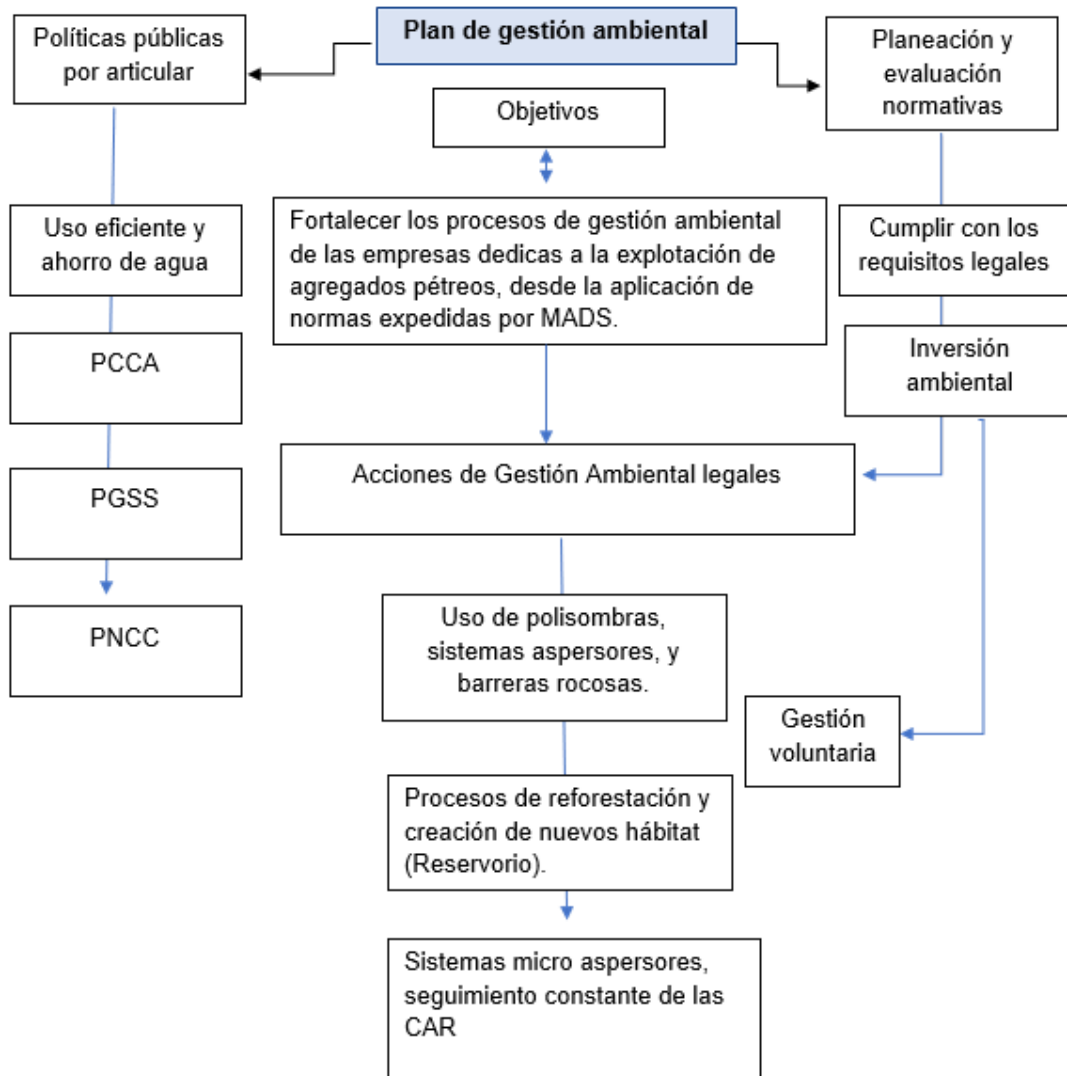
Table 2. List of compliance/non-compliance with national environmental regulations issued by the Ministry of Environment and Sustainable Development, in connection with the exploitation of stone aggregates

Rule / Law / Decree	Scope	Orión Asfaltos y Concretos S.A.S.	Agrego Ltda.	Agregados Rio Negro.	Observations
Decree No. 1299/08	Environmental management	Yes	Yes	Yes	All three companies have an incorporation record of an environmental
Decree No. 1541/78	Permit to capture water	Yes	Yes	No	Agregados Rio Negro does not comply with this regulation
Solid Waste Management					
Decree No. 4741/05	Hazardous waste plan	No	No	No	No hazardous waste plan
Resolution No. 2184/2019	Solid waste sorting	Yes	Yes	Yes	They have ecological points with colors in compliance with the new regulation
Decree No.1713/02	Waste Disposal	Yes	Yes	Yes	INTERASEO S.A.S. E.P.S.
Atmospheric emissions					
Resolución No. 909/200	Incineration	Not applicable	Not applicable	Not applicable	Not necessary in production
Resolución No.	Fixed source	Yes	Yes	No	All three companies
Decree No.948 /95	Emissions control	No	Yes	No	Partial compliance
Resolución No. 0937/0	Noise	Yes	Yes	Yes	Studies and control
Single Regulatory	Air	Yes	Yes	No	Partial compliance

Source: Prepared by the authors, adapted from the Ministry of Environment and Sustainable Development

It is worth highlighting the role of these regulations in bringing companies closer to meeting the environmental requirements of Autonomous Corporations [40]. About the compliance table (see Table 2), it should be mentioned that Agregados Rio Negro does not comply with environmental regulations. However, it is essential to complete the processes of requesting emissions permits for fixed sources, as it is one of the main reasons why mines can be closed. After receiving the environmental sanction, Orion Asfaltos y Concretos S.A.S. created a contingency plan to comply with the relevant requirements. It is now compliant with the regulations.

Figure 4. Strategic environmental management plan for stone aggregates mining companies in the Department of La Guajira



Source: Prepared by the authors

The proposed strategy covers public policies to be articulated for the minimization and control of impacts from the regulatory approach, supported by a series of monitoring plans according to each environmental factor for this case (water, air, soil, fauna, and flora). The design of this type of model determines the direct capacity of each company to adopt the most financially viable strategies. There, the environmental investment is key, and it will depend not only on the production but also on the voluntary management of each company's managers.

Regulations require strategic plans to be adapted according to the needs of each organization, together with its production phases and the environmental impact it generates. From the regulatory framework approach, the articulation of environmental public policies symbolizes the possibility of envisioning production around sustainable development, considering its fundamental pillars from the economic, social, and environmental spheres, thereby generating a commitment in the territories where they are implemented. The application of any action in favor of the environment provides added value to the companies, causing an impact in the national and international markets.

It is necessary to highlight that for the compliance and execution of these types of actions, each organization must

work hand in hand with the Regional Autonomous Corporation, which is in charge of monitoring and evaluating the compliance and relevance of these actions. Monitoring schedules are designed by the same entity, which is responsible for deciding the variability. This facilitates compliance with the agreements made in the visits and makes organizations comply with priority tasks [41]. The importance of these types of corporate entities is their relation with the highest environmental control body in terms of environmental regulations, which is the Ministry of Environment and Sustainable Development.

Finally, Agregom Ltda. has renewed its emissions permit as per the current law. However, in the last regular visit by the Regional Autonomous Corporation, it received a warning because it failed to have a management plan for the treatment of hazardous waste, which could affect the ecosystem. It is important for organizations to make responsible use of natural resources to preserve the integrity of the Guajira territory. The three mines lack strategic plans with management measures adapted to each need, and it is important to abide by the public policies on the mining sector. In view of the environmental problems of the organizations, an environmental management plan is proposed, linked to the planning and evaluation of environmental regulations, to comply with the public policies on mining.

Conclusions

After analyzing the results obtained through the study, the following conclusions can be reached: 1) The Colombian environmental regulations issued by the Ministry of Environment and Sustainable Development are a key tool for promoting environmental management processes within the mining companies of stone aggregates in La Guajira. However, compliance with these regulations by the organizations is only partial. Therefore, there is a need to strengthen monitoring by entities with jurisdiction to promote the care of environmental factors based on the law. 2) The companies Agregom Ltda., Orión Asfaltos y Concretos S.A.S., and Agregados Rio Negro comply with the environmental licenses granted by Corpoguajira. However, there is an inconsistency in the environmental management processes, influenced by the lack of an Environmental Impact Plan (PIA for its acronym in Spanish) and the absence of a management plan associated with each of the production phases to comply with the requirements of the regulations. 3) In general, the three companies fail to comply with current regulations due to the fact that currently repealed norms are in force, specifically those associated with air quality and integral solid waste management. Abiding by environmental public policies is necessary to consolidate sustainable development through environmental management measures that prevent, control, minimize, and restore environmental damage caused by production actions and redirect to environmental management. 4) These companies have a demanding need from the regulatory point of view since compliance with the regulations exempts them from being exposed to environmental sanctions. This indicates a need to consolidate a good culture in relation to the environment since the three organizations have received warnings through judgments and even temporary closures of production units. 5) Finally, strengthening environmental management with the application of regulations is a challenging process that must be consolidated in the organizations, with internal advice from Regional Autonomous Corporations, despite the fact that the requirements set forth in the regulations are clear. 6) The instrument used was effective in identifying what compliance with environmental regulations is like in mining companies of stone aggregate materials in the department of La Guajira, providing useful information for studies covering the same area of reference.

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